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"EMU sovereign debt market crisis: Fundamentals-based or pure contagion?"

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Abstract

We empirically investigate whether the transmission of the recent crisis in euro area sovereign debt markets was due to fundamentals-based or pure contagion. To do so, we examine the behaviour of EMU sovereign bond yield spreads with respect to the German bund for a sample of both central and peripheral countries from January 1999 to December 2012. First we apply a dynamic approach to analyse the evolution of the degree of Granger-causality within the 90 pairs of sovereign bond yield spreads in our sample, in order to detect episodes of significantly increased causality between them (which we associate with contagion) and episodes of significantly reduced interconnection (which we associate with immunisation). We then use an ordered logit model to assess the determinants of the occurrence of the episodes detected. Our results suggest the importance of variables proxying market sentiment and of variables proxying macrofundamentals in determining contagion and immunisation outcomes. Therefore, our findings underline the coexistence of "pure" and "fundamentals-based contagion" during the recent European debt crisis.

JEL classification: C35, C53, E44, F36, G15
Keywords: Sovereign bond spreads, contagion, Granger-causality, time-varying approach, euro area, ordered logit model.

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1. Introduction

The announcement of Greece's distressed debt position in late 2009 triggered a sudden loss of investor confidence and marked the beginning of the euro area sovereign debt crisis. Indeed, in May 2010 Greece's financial problems became so severe that the country needed to be bailed out. An important reason for providing financial support to Greece was fear of contagion (see, for instance, Constâncio, 2012), not only because several European Union banks had a high exposure to Greece (see Gómez-Puig and Sosvilla-Rivero, 2013a), but also because the investors now turned their attention to the macroeconomic and fiscal imbalances within European Economic and Monetary Union (EMU) countries, which had largely been ignored until then (see Beirne and Fratzscher, 2013). So, from late 2009 onwards, in parallel with the higher demand for the German bund which benefited from its safe haven status, yield spreads of euro area issues with respect to Germany spiralled (see Figure 1). Besides, since May 2010, not only has Greece been rescued twice, but also Ireland, Portugal and Cyprus have needed bailouts to stay afloat.

These events raised some important questions for economists, policymakers, and practitioners. To what extent was the sovereign risk premium increase in the euro area during the European sovereign debt crisis due only to deteriorated debt sustainability in member countries? Did contagion play any significant role in the increase in the sovereign risk premium? In fact the sovereign debt crisis in Europe has rekindled the literature on contagion applied to the euro area [see Kalbaska and Gatkowski (2012), Metiu (2012), Caporin *et al.* (2013), Beirne and Fratzscher (2013) and Mink and Haan (2013) to name a few], even though the empirical evidence is not conclusive. The discrepancies and inconsistencies between studies using different empirical approaches and applying different definitions of the crisis transmission channel have made it difficult to compare results and therefore to reach meaningful conclusions (Dungey *et al.*, 2005). The main objective of this paper is to shed some light on this challenging avenue of research.

The first challenge is to provide a precise definition of contagion, since at present the term is used quite ambiguously in the literature. Nor is there any agreement on the econometric methodology to be used. So, the second challenge is an empirical one: contagion is an unobservable shock, and therefore most empirical techniques have problems dealing with latent variables.

In this paper, in order to evaluate the extent of contagion in the euro area, we first test for the existence of possible Granger-causal relationships between 10-year sovereign yield spreads over Germany of 10 EMU countries, both central (Austria, Belgium, Finland, France and The Netherlands) and peripheral (Greece, Ireland, Italy, Portugal and Spain). Secondly, we examine the time-varying nature of these relationships in order to detect episodes of significant intensification or reduction in the causality between them. Finally, we explore whether there is evidence of "pure contagion" or "fundamentals-based contagion" in the euro area sovereign debt crisis, by trying to determine which factors (changes in local risk sentiment in each different country, fundamental variables, financial linkages, or common regional/global risk factors) might have been behind these intensification/reduction episodes.

The rest of the paper is organised as follows. Section 2 reviews the literature on financial contagion and on the determinants of euro-area sovereign bond spreads. The Granger-causality analysis and our approach for the detection of episodes of intensification/reduction of causality are presented in Section 3. In Section 4 we carry out the empirical exploration of the determinants of these episodes. Finally, Section 5 summarises the findings and offers some concluding remarks.

2. Literature review

2. 1. Financial contagion

Considerable ambiguity surrounds the precise definition of contagion. There is no theoretical or empirical definition on which all researchers agree; therefore, the debate on exactly how to define contagion is not just academic, but has important implications for measuring the concept and for evaluating policy responses. Pericoli and Sbracia (2003) note five definitions of contagion used in the literature, whilst The World Bank defines three layers within contagion[1]. First, in a broad sense, contagion is the cross-country transmission of shocks or general cross-country spillover effects; in this sense, contagion can take place both during "good" and "bad" times and does not need to be related to crises. Second, in a restrictive sense, contagion is the transmission of shocks to other countries, or the cross-country correlation, beyond any fundamental link[2] between the countries and beyond common shocks. When either fundamentals or common shocks do not fully explain the relationship between countries, spillover effects are attributed to herding behaviour, either rational or irrational. Finally, in a very restrictive sense, according to the World Bank, contagion refers to increases in cross-country correlations during "crisis times" relative to correlations during "tranquil times".

The second and third definitions of contagion proposed by the World Bank (contagion in a restrictive, and in a very restrictive sense) have predominantly been used in empirical studies analysing the concept in financial markets and have been adopted in common usage by governments, citizens and policymakers. The third defines contagion depending on whether the transmission mechanisms are stable through time,

[1]http://go.worldbank.org/JIBDRK3YC0

[2] The World Bank distinguishes three different categories of fundamental links: financial, real, and political. The first ones exist when two economies are connected through the international financial system. Real links are fundamental economic relationships between countries. These links have usually been associated with international trade, but other types of real links, like foreign direct investment across countries, may also be present. Finally, political links are the political relationships between countries. Although this link is much less stressed in the literature, when a group of countries share an exchange rate arrangement – a common currency in the case of the euro area countries – crises tend to be clustered.

whilst the second defines it depending on the channels of transmission that are used to spread the effects of the crisis.

According to the very restrictive definition, which was proposed in a seminal paper by Forbes and Rigobon (2002), contagion is a significant increase in cross-market linkages after a shock to one country (or group of countries). Therefore, if two markets show a high degree of co-movement during periods of stability, even if they continue to be highly correlated after a shock to one market this may not constitute contagion. This definition implies the presence of a tranquil, pre-crisis period. The distinction between contagion which occurs at times of crisis, and the interdependence which is the result of normal market interaction, has become the focal point of many contagion studies (see, e.g., Corsetti *et al.,* 2005 or Bae *et al.*, 2003).

By contrast, Calvo and Reinhart (1996), Masson (1999), and Kaminsky and Reinhart (2000) explore the restrictive definition of contagion, arguing that contagion arises when common shocks and all channels of potential interconnection are either not present or have been controlled for. According to these authors, "pure or true contagion" should be distinguished from "fundamentals-based contagion" which is caused by "monsoonal effects" and "linkages". "Monsoonal effects" are random aggregate shocks that hit a number of countries in a similar way (such as a major economic shift in industrial countries, a significant change in oil prices or changes in US interest rates) that may adversely affect the economic fundamentals of several economies simultaneously and, therefore, may cause a crisis (Eichengreen *et. al.*, 1996). "Linkages" are normal interdependencies, such as those produced by trade and financial relations between countries and which can easily become a carrier of crisis (Kaminsky and Reinhart, 2000).

Conversely, the term "pure contagion" is only applied when the transmission process itself changes when entering crisis periods: when a crisis in one country may conceivably trigger a crisis elsewhere for reasons unexplained by macroeconomic fundamentals – perhaps because it leads to shifts in market sentiment, or changes the interpretation given to existing information, or triggers herding behaviour (Claessens *et al.*, 2001). Different mechanisms have been proposed to explain herding behaviour by international investors and other cases of extreme market sentiment (see Lux, 1995; or Akerlof and Shiller, 2009). The literature has emphasised that asymmetric information is at the root of these market reactions. Information is costly, so investors do not know enough about the countries in which they invest and therefore try to infer future price changes based on how the rest of the market is reacting. The relatively uninformed investors follow the supposedly informed investors, and all the market moves jointly.

All in all, then, the literature includes two groups of theories (not necessarily mutually exclusive – see Dungey and Gajurel, 2013) to explain crisis transmission mechanisms. One group argues that the economic fundamentals of different countries are interconnected by their cross-border flows of goods, services, and capital. When a crisis originates in one country, this interdependence of economies through real and financial linkages may become a conveyor of crisis. In addition, global phenomena or common shocks may adversely affect the economic fundamentals of several economies simultaneously, and may therefore cause a crisis. These fundamentals-based effects are also known as 'spillovers' (Masson, 1999), 'interdependence' (Forbes and Rigobon, 2002), or 'fundamentals-based contagion' (Kaminsky and Reinhart, 2000).

The other group of theories argues that financial crisis spreads from one country to another due to market imperfection or the behaviour of international investors (Masson, 1999). Information asymmetries make investors more uncertain about the actual economic fundamentals of a country. A crisis in one country may give a "wake-up call" to international investors to reassess the risks in other countries; uninformed or less informed investors may find it difficult to extract the informed signal from the falling price and follow the strategies of better informed investors, thus generating excess co-movements across the markets. The degree of non-anticipation of a crisis by investors or sudden shifts in market confidence and expectations have been identified as important factors causing "pure contagion" (see Masson, 1999 and Mondria and Quintana-Domeque, 2013).

The initial empirical literature on financial crisis and contagion was focused on fundamentals-based mechanisms and directed towards developing an early warning system (Eichengreen *et al.*, 1996; Kaminsky *et al.*, 2000) while later empirical works have focused on investor behaviour-based mechanisms (Dungey *et al.*, 2005; Bekaert *et al.,* 2011). The aim of this paper is to explore the extent to which the transmission of euro area debt crisis could be attributed to common shocks and/or interconnected markets (through real and financial linkages), to idiosyncratic factors (shifts in market participants behaviour during the crisis period), or to both types of factor. To this end, we will analyse which variables could be behind the crisis transmission in order to assess whether there is empirical evidence of "fundamentals-based contagion", or "pure contagion", or of a mixture of the two during the euro area sovereign debt crisis.

In addition, among the five general strategies[3] that have been used in the empirical literature, our analysis will be related to one of the most conventional methodologies for testing for contagion: the analysis of cross-market correlations. However, we not only investigate changes in cross-market interdependencies via cointegration analysis, but also explore changes in the existence and direction of pair-wise causal

[3] Probability analysis, cross-market correlations, VAR models, latent factor/GARCH models, and extreme value/co-exceedance/jump approach (see Forbes, 2013).

relationships among euro area sovereign bond yield spreads vis-à-vis the German bund[4]. Hence, the two operational definitions of contagion that we will explore in the remainder of this paper are the following. We will identify "fundamentals-based contagion" as an abnormal increase in the intensity of causal relationships explained by macroeconomic fundamentals, financial linkages or common regional/global shocks, and "pure contagion" as an abnormal increase in the intensity of causal relationships only triggered by a shift in idiosyncratic market sentiments.

2.2. Determinants of the evolution of euro-area sovereign yield spreads.

In order to analyse the factors behind episodes of intensification/reduction of causality within sovereign yield spreads, we focused on the literature on the determinants of the evolution of euro-area sovereign yield spread. This literature, combined with that of financial contagion, suggests that we should not only include variables that measure macroeconomic fundamentals or some potential channels of crisis transmission, but also those that capture changes in market sentiment: either idiosyncratic, regional, or global[5]. A summary with the definition and sources of all the explanatory variables used in the ordered logit model is presented in Appendix A.

Specifically, four variables have been used to gauge regional, global or local market sentiment in each different country: stock returns, stock volatility, an index of economic policy uncertainty, and an index of the fiscal stance.

Monthly stock returns are used in order to reflect portfolio allocation effects between stocks and bonds in each country (see among others, Aizenman, 2013 and Georgoutsos and Migiakis, 2013). Since periods of financial turmoil and negative stock returns may be accompanied by rises in sovereign bond spreads because of an increased propensity to hold safer assets (the German bund in our case), we expect a negative association between them. To this end, differences of logged stock index prices of the last and the first day of the month have been calculated for the benchmark stock index in each country; whilst the Eurostoxx-50 and the Standard and Poor's 500 have been used to calculate, respectively, the evolution of regional and global stock returns. Volatility is a measure of the level of uncertainty prevailing in stock markets. Two different approaches are used to estimate it; while historical volatility involves measuring the standard deviation of closing returns for any particular security over a given period of time, implied volatility is derived from option prices. The latter represents the estimates and assumptions of market participants involved in a trade, on the basis of a given option price, and has been used to gauge both regional and global stock market volatility. In particular, the variables VSTOXX and VIX which measure

[4] Forbes and Rigobon (2002) suggest the use of this methodology and note that, if the source of the crisis is not well identified and endogeneity may be severe, it may be useful to utilise Granger-causality tests to determine the extent of any feedback from each country in the sample to the initial crisis country.

[5] We expect the same sign for the effect of each of these variables on spreads and on the occurrence of a contagion episode.

implied volatility in Eurostoxx-50 and Standard and Poor's 500 index options and have been widely used in the literature by other authors (see, e.g., Afonso, 2012, Aizenman *et al*., 2013, and Battistini *et al*., 2013) have been incorporated as measures of uncertainty in the Eurozone and the global financial markets respectively. However, since the implied volatility indices were not available for all countries, we opted for the monthly standard deviation of equity returns in each country to capture local stock market volatility. The increased stock market volatility is usually accompanied by an increase in other risk components and, thus, leads to increases in bond yield spreads; as a result, we expect a positive sign for the respective coefficient.

Some authors (see, e.g. Ades and Chua, 1993) find that political instability has strong negative effects on a country's per capita growth rate. Thus, to assess whether policy uncertainty has an influence on the decisions of bond market investors, we have used the index of economic policy uncertainty (EPU), built up by Baker *et. al*. (2013), which draws on the frequency of newspaper references to policy uncertainty and other indicators and which is available for Germany, France, Italy, Spain, Europe and the United States. A positive sign is also expected for the respective coefficient since policy uncertainty may discourage investments in sovereign debt markets. A related question is the analysis of the impact of the fiscal stance of each country on sovereign debt spreads. Therefore, the index of the fiscal stance suggested by Polito and Wickens (2011, 2012) is also included in the analysis. Unlike the standard econometric tests of fiscal sustainability, this index is suitable for assessing fiscal policy in the short and medium term as it can measure the fiscal consolidation needed to achieve a pre-specified debt target at any future time horizon. To capture regional and global risk we have used the European and United States indices of the fiscal stance respectively. Since, by construction, the higher the index, the worse the fiscal stance, we expect a positive sign for its coefficient.

Another variable, the consumer confidence indicator[6], has been used to measure either regional (Eurozone) or local market sentiment in each different country. This index is used to gauge economic agents' perceptions of future economic activity and it seems reasonable to expect a negative relationship between it and spreads, since an increase in consumer confidence may lead to a rise in investor confidence in the economy's potential for growth.

Finally, the analysis of the influence of local, regional and global market sentiment on sovereign yield spreads has been completed by the inclusion of one more variable in the first case, five additional variables in the second, and two supplementary variables in the third.

[6] According to some authors (see, e.g., Rua, 2002), the Economic Sentiment Indicator (ESI) has informative content for the GDP growth rate and can therefore be used to gauge economic agents' perceptions of future economic activity. However, since this indicator was not available for Ireland, and the correlation between the Consumer Confidence Indicator and the ESI is very high, we decided to include the former in the analysis.

Credit rating has been included as a proxy of the market perception of default risk in each local market. So, following Blanco (2001), we built up a monthly scale to estimate the effect of investor sentiment based on the rating offered by the three most important agencies (Standard &Poor's, Moody's and Fitch). Since this variable is considered an *ex post* measure of fiscal sustainability it should have a positive impact on sovereign spreads (by construction, the higher the scale, the worse the rating categories).

Five variables have been added to explore the impact of regional market sentiment on sovereign spreads. First, we have accounted for the effects of the prevailing credit risk conditions in the European corporate bond market. Following Georgoutsos and Migiakis (2013), the indices (iBoxx) of European corporate bonds with a rating of BBB have been used in order to obtain the spread between their yields, since they are commonly used as a proxy of the effects that changes in credit risk conditions in the European corporate bond market exercise on European sovereign bond spreads. Furthermore, to capture the full spectrum of credit quality in the euro area corporate market, we have also included the evolution of two indices: the $ITRAXX_{FIN}$ and the $ITRAXX_{NF}$. These are European 5-year CDS indices in the financial and the non-financial sector respectively (the corresponding indices for the United States have been widely used in the literature: see, for instance, Gilchrist *et. al.*, 2013). Considering the "safe haven" status of the German bund, we expect these two variables, which measure credit risk in the corporate bond market, to be positively related to the spreads.

Moreover, one- and ten-year interest rate volatility indices for the Eurozone (EIRVIXs) based on the implied volatility quotes of caps (floors) – one of the most liquid interest rate derivatives, constructed by López and Navarro (2013) – have also been incorporated in the analysis. A positive sign is also expected for these variables, since increased interest rate volatility is usually accompanied by an increase in yield spread volatility. To account for the concerns for the stability of the euro we have used the indicator built up by Klose and Weigert (2012) which reflects the market expectation of the probability that at least one euro area country will have left the currency union by the end of 2013. Finally, to measure the joint default risk in the euro area, we include the time-varying probability of two or more credit events (out of ten) over a one-year horizon calculated by Lucas *et al.* (2013). A positive relationship is also expected between the last two variables (which measure uncertainty and default risk in the euro area) and sovereign yield spreads.

As mentioned, two supplementary variables have also been introduced in the model in order to assess global market risk aversion. Firstly, following the empirical literature on sovereign bond spreads in emerging markets, which shows that yields on US government bonds are the main determinants of sovereign spreads, the spread between 10-year fixed interest rates on US swaps and the yield on 10-year

Moody's Seasoned AAA US corporate bonds is also introduced as a proxy of international risk factors (see Codogno *et al.*, 2003 and Gómez-Puig, 2008). Secondly, we have included the Kansas City Financial Stress Index built by Hakkio and Keeton (2009), which is a monthly measure of stress in the U.S. financial system based on 11 financial market variables (a positive value indicates that financial stress is above the long-run average, while a negative value signifies that financial stress is below the long-run average). Therefore, a positive relationship is also expected between these two variables and sovereign spreads.

On the other hand, in order to measure the impact of fundamental variables (at both the local and the regional level) on sovereign spreads behaviour, we use instruments that gauge not only each country's fiscal position, but the market liquidity in each country, its foreign debt, its potential rate of growth, and the loss of competitiveness as well. The private sector level of indebtedness has been added in the analysis of the effect of local fundamental variables and, finally, we have included foreign claims on sectoral private debt and cross-border banking system linkages as measures of the degree of crisis transmission through the financial system (see Gómez-Puig and Sosvilla-Rivero, 2013a).

Specifically, the variables used to measure the country's fiscal position are the government debt-to-GDP and the government deficit-to-GDP. These two variables have been widely used in the literature by other authors (see, e.g., Bayoumi *et al.*, 1995) and present an advantage over the credit rating in that they cannot be considered *ex post* measures of fiscal sustainability. Since they are measures of credit risk, they should be directly related with sovereign spreads increase.

Regarding the liquidity premium in each sovereign debt market, empirical papers examining the influence of market liquidity in bond markets use a variety of measures to gauge its three main dimensions of tightness, depth and resiliency. These measures include trading volume, bid-ask spreads, the outstanding amount of debt securities, and the issue size of the specific bond. However, several studies have shown that all liquidity measures are closely related to each other [Gómez-Puig (2006), Korajczyk and Sadka (2008), and Gerlach *et al.* (2010) to name a few]. Therefore, we think that the overall outstanding volume of sovereign debt – which is considered a measure of market depth because larger markets may present lower information costs as their securities are likely to trade frequently, and a relatively large number of investors may own or may have analysed their features – might be a good proxy of liquidity differences between markets. Since liquidity premium decreases with market size, we would expect a negative effect of this variable on sovereign spreads.

Besides, the current-account-balance-to-GDP ratio is the instrument used as a proxy of the foreign debt and the net position of the country vis-à-vis the rest of the world. Note that this variable is defined as the difference between exports and imports. Therefore an increase would signal an improvement in the net position of the country towards the rest of the world, reducing sovereign spreads. The importance of this variable has been underlined by the IMF (2010) and Barrios *et al.* (2009). In view of Mody (2009)'s argument that countries' sensitivity to the financial crisis is more pronounced the greater the loss of their growth potential and competitiveness, we include instruments that measure these features. The unemployment rate is the variable used to capture the country's growth potential, whilst the Harmonized Index of Consumer Prices monthly interannual rate of growth is the inflation rate measure we use as a proxy of the appreciation of the real exchange rate and, thus, the country's loss of competitiveness. An increase in either unemployment or inflation represents a deterioration of growth potential and competitiveness; so, it should augment sovereign spreads.

To assess the role of private debt in the euro area sovereign debt crisis, we also incorporate instruments that capture the level of indebtedness of each country's private sector in the analysis. To that end, we make use of a unique dataset on private debt-to-GDP by sector in each EMU country. In particular, we use three variables: banks' debt-to-GDP, non-financial corporations' debt-to-GDP, and households' debt-to-GDP, which have been constructed with data obtained from the European Central Bank Statistics. Since high leverage levels in the private sector have a negative impact on the public sector's sustainability, an increase in these three variables would positively affect sovereign yield spreads.

Finally, according to certain authors [Bolton and Jeanne (2011) and Allen *et al.* (2011) among them], in a scenario of increased international financial activity in the euro area, not only are public finance imbalances key determinants of the probability that the sovereign debt crisis could spill over from one country to another, but the transmission of the crisis through the banking system can also be a major issue. As a result, in our analysis we also include variables that capture the important cross-border banking system linkages in euro area countries. These linkages are measured using the consolidated claims on an immediate borrower basis of Bank for International Settlements (BIS) reporting banks in the public, banking and non-financial private sectors as a proportion of GDP. Moreover, we also explore the role of consolidated claims on an immediate borrower basis provided by BIS by nationality of reporting banks as a proportion of total foreign claims on each country. We expect that higher banking sector exposure and cross-border banking system linkages will be associated with an increase in sovereign spreads[7].

3. Granger-causality analysis

3. 1. Econometric strategy

[7] The construction and evolution of sectoral private debt, foreign banks claims by sector and by nationality of reporting banks are explained in Gómez-Puig and Sosvilla-Rivero (2013a).

The concept of Granger-causality was introduced by Granger (1969) and Sims (1972) and is widely used to ascertain the importance of the interaction between two series. The central notion is one of predictability (Hoover, 2001): a variable Y is said to Granger-cause another variable X if past values of Y help predict the current level of X better than past values of X alone, indicating that past values of Y have some informational content that is not present in past values of X. Therefore, knowledge of the evolution of the variable Y reduces the forecast errors of the variable X, suggesting that X does not evolve independently of Y.

Tests of Granger causality typically use the same lags for all variables. This poses a potential problem, since Granger-causality tests are sensitive to lag length[8]. In determining the optimal lag structure for each variable, we follow Hsiao's (1981) sequential method to test for causality, which combines Akaike's final predictive error (FPE, from now on) and the definition of Granger-causality[9]. Essentially, the FPE criterion trades off the bias that arises from under-parameterisation of a model against a loss in efficiency resulting from its over-parameterisation, removing the ambiguities of the conventional procedure.

Consider the following models,

$$X_{\mathrm{t}} = \alpha_0 + \sum_{i=1}^{m} \delta_i X_{t-i} + \varepsilon_t \tag{1}$$

$$X_t = \alpha_0 + \sum_{i=1}^{m} \delta_i X_{t-i} + \sum_{j=1}^{n} \gamma_j Y_{t-j} + \varepsilon_t \tag{2}$$

where X_t and Y_t are stationary variables [i.e., they are I(0) variables]. The following steps are used to apply Hsiao's procedure for testing Granger-causality:

i) Treat X_t as a one-dimensional autoregressive process (1), and compute its FPE with the order of lags m varying from 1 to m[10]. Choose the order which yields the smallest FPE, say m, and denote the corresponding FPE as FPE_X (m, 0).

ii) Treat X_t as a controlled variable with m number of lags, and treat Y_t as a manipulated variable as in (2). Compute again the FPE of (2) by varying the order of lags of Y_t from 1 to n, and determine the order which gives the smallest FPE, say n, and denote the corresponding FPE as FPE_X (m,n)[11].

[8] The general principle is that smaller lag lengths have smaller variance but run a risk of bias, while larger lags reduce the bias problem but may lead to inefficiency.

[9] Thornton and Batten (1985) show that Akaike's FPE criterion performs well relative to other statistical techniques.

[10] $FPE_X(m,0)$ is computed using the formula: $FPE_X(m,0) = \frac{T+m+1}{T-m-1} \cdot \frac{SSR}{T}$, where T is the total number of observations and SSR is the sum of squared residuals of OLS regression (1)

[11] $FPE_X(m,n)$ is computed using the formula: $FPE_X(m,n) = \frac{T+m+n+1}{T-m-n-1} \cdot \frac{SSR}{T}$, where T is the total number of observations and SSR is the sum of squared residuals of OLS regression (2)

iii) Compare FPE_X (m, 0) with FPE_X (m,n) [i.e., compare the smallest FPE in step (i) with the smallest FPE in step (ii)]. If FPE_X (m,0) > FPE_X (m,n), then Y_t is said to cause X_t. If FPE_X (m,0) < FPE_X (m,n), then X_t is an independent process.

iv) Repeat steps i) to iii) for the Y_t variable, treating X_t as the manipulated variable.

When X_t and Y_t are not stationary variables, but are first-difference stationary [i.e., they are I(1) variables] and cointegrated (see Dolado *et al.,* 1990), it is possible to investigate the existence of Granger-causal relationships from ΔX_t to ΔY_t and from ΔY_t to ΔX_t, using the following error correction models:

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{m} \delta_i \Delta X_{t-i} + \varepsilon_t \tag{3}$$

$$\Delta X_t = \alpha_0 + \beta Z_{t-1} + \sum_{i=1}^{m} \delta_i \Delta X_{t-i} + \sum_{j=1}^{n} \gamma_j \Delta Y_{t-j} + \varepsilon_t \tag{4}$$

where Z_t is the OLS residual of the cointegrating regression ($X_t = \mu + \lambda Y_t$), known as the error-correction term. Note that, if X_t and Y_t are I (1) variables, but they are not cointegrated, then β in (4) is assumed to be equal to zero.

In both cases [i.e., X_t and Y_t are I(1) variables, and they are or are not cointegrated], we can use Hsiao's sequential procedure substituting X_t with ΔX_t and Y_t with ΔY_t in steps i) to iv), as well as substituting expressions (1) and (2) with equations (3) and (4). Proceeding in this way, we ensure efficiency since the system is congruent and encompassing (Hendry and Mizon, 1999).

3. 2. Data

The dependent variables in our empirical analysis are bond yield spreads, derived as differences between 10-year sovereign bond yields of EMU-founding countries and Greece and yields of the equivalent German bund. Therefore, our sample contains both central (Austria, Belgium, Finland, France and the Netherlands) and peripheral countries (Greece, Ireland, Italy, Portugal and Spain) [12].

We use daily data from 1 January 1999 to 31 December 2012 collected from Thomson Reuters Datastream. Figure 1 plots the evolution of daily 10-year sovereign bond spreads for each country in our sample. A simple look at this figure indicates the differences in the yield behaviour before and after the outbreak of the Greek sovereign debt crisis at the end of 2009.

[Insert Figure 1 here]

[12] Luxembourg is exempted from the present analysis, because of its very low level of outstanding sovereign bonds.

Specifically, it is striking that between the introduction of the euro in January 1999 and November 2009, when it became clear that the Greek economy faced the bleak reality of being unable to finance its sovereign debt, spreads on bonds of EMU countries moved in a narrow range with only slight differentiation across countries. In fact, the stability and convergence of spreads was considered a hallmark of successful financial integration inside the euro area (neither the subprime crisis nor the Lehman Brothers collapse bit significantly into euro sovereign spreads).

Nevertheless, once the global financial crisis began to affect the real sector, the imbalances within euro area countries were plain to see. Spreads, which had reached levels close to zero between the launch of the euro and October 2009 (the average value of the 10-year yield spread against the German bund moved between 10 and 47 basis points in the case of France and Greece respectively), have risen ever since. Indeed, the risk premium on EMU government bonds increased strongly from November 2009, reflecting investor perceptions of upcoming risks. Figure 1 shows that by late 2011 and beginning 2012 it reached maximum levels of 4680 basis points in Greece, 1141 in Portugal, 1125 in Ireland, 635 in Spain and 550 in Italy. This widespread increase in sovereign spreads meant that certain euro area Member States were under enormous pressure to finance their debt, and funding costs rose significantly. This led to an increase in rollover risk as debt had to be refinanced at unusually high costs and, in extreme cases, could not be rolled over at all, which triggered the need for a rescue (see Caceres, 2010).

3.3. Preliminary results

As a first step, we tested the order of integration of the 10-year bond yields by means of the Augmented Dickey-Fuller (ADF) tests. Then, following Cheung and Chinn (1997)'s suggestion, we confirmed the results using the Kwiatkowski *et al.* (1992) (KPSS) tests, where the null is a stationary process against the alternative of a unit root. The results, not shown here to save space but available from the authors upon request, decisively reject the null hypothesis of non-stationarity in the first regressions. They do not reject the null hypothesis of stationarity in first differences, but strongly reject it in levels, in the second ones. So, they suggest that both variables can be treated as first-difference stationary.

As a second step, we tested for cointegration between each of the 45 pair combinations[13] of EMU yields using Johansen (1991, 1995)'s approach. The results suggest[14] that only for the Greece-Ireland and Greece-Portugal cases does the trace test indicate the existence of one cointegrating equation at (at least)

[13] Recall that the number of possible pairs between our sample of ten EMU yield spreads with respect to Germany is given by the following formula $\frac{n!}{r!(n-r)!} = \frac{10!}{2!(10-2)!} = 45$.

[14] Again, the results are not presented in the interests of space, but are available from the authors upon request.

the 0.05 level. Therefore, for these two pairs we test for Granger-causality in first differences of the variables, with an error-correction term added [i. e., equations (3) and (4)], whereas for the remaining cases, we test for Granger-causality in first differences of the variables, with no error-correction term added [i. e., equations (3) and (4) with β=0]

3.4. Empirical results

The resulting FPE statistics for the whole sample suggest bidirectional Granger-causality in almost all cases[15]. However, there are some exceptions. We do not find unidirectional Granger-causality in the relationships running from Austria to Ireland, from Finland to France, from France to Ireland and from Greece to Ireland. Nor do we find bidirectional Granger-causality relationships between Austria and Portugal, or between Finland and Greece. However, in order to assess the dynamic Granger-causality between the 90 possible EMU yield spreads relationships, we carried out 309,500 rolling regressions using a window of 200 observations[16]. In each estimation, we apply Hsiao (1981)'s sequential procedure outlined above to determine the optimum FPE (m, 0) and FPE (m, n) statistics in each case. We find sub-periods of Granger-causality in all pair-wise relationships, even for those relationships where we found rejection when performing the tests for the whole sample.

After examining the time-varying nature of causal relationships, we proceed further by identifying sub-periods of significant increase/decrease in Granger-causality in order to identify the factors that may have been behind them. To this end, we identify episodes of Granger-causality intensification such as those in which the time-varying Granger-causality indicator is greater than its average plus two standard errors[17]. Therefore, we look for episodes where there is evidence of an enhancement in the information content of the yield spread series that significantly improves the explanatory power of the future evolution of the other yield spread series, suggesting a strengthening of their interdependence. Likewise, we identify episodes of reduction in the interconnection between the series under study as those in which the time-varying Granger-causality indicator is lower than its average minus two standard errors. Hence, in this latter case, we search for episodes where there is evidence that the information content of the yield spread series significantly reduces the explanatory power of future evolution of the other yield spread series[18]. We

[15] These results are also available from the authors upon request. The results were confirmed using both Wald statistics to test the joint hypothesis $\hat{\gamma}_1 = \hat{\gamma}_2 = \ldots = \hat{\gamma}_n = 0$ in equations (2) or (4) and the Williams-Kloot test for forecasting accuracy (Williams, 1959).

[16] To the best of our knowledge, there is no statistical method to set the optimal window size. The chosen value of 200 observations is representative of the one used in practice and seems appropriate for our empirical application since it represents 6.36% of the sample. We have also used a value of 100 observations. The results (not shown here to save space but available from the authors upon request) render the same qualitative conclusions as when 200 observations were used.

[17] We perform formal tests to evaluate whether the series have the same mean during the detected episodes and the rest of the observations. The results of these tests (not shown here, but available from the authors upon request) strongly reject the null hypothesis of equal mean across sub-samples, and provide additional support for the presence of increased Granger-causality.

[18] Indeed, the manipulated variable in equations (2) or (4) not only does not contribute to a better prediction of the controlled variable, but its inclusion actually renders the prediction worse, signaling that its information content is not relevant for the future evolution of the manipulated variable.

associate episodes of Granger-causality intensification with episodes of contagion, and episodes of causality reduction with episodes of immunisation[19].

The graphs in Figures 2 suggest that these episodes are concentrated around the first year of the existence of the EMU in 1999, the introduction of euro coins and banknotes in 2002, and the global financial crisis of the late 2000s. Specifically, Figures 2a to 2e represent the time-varying evolution of these intensification/reduction episodes within all EMU countries (Figure 2a), within peripheral countries (Figure 2b), from peripheral to central countries (Figure 2c), within central countries (Figure 2d), and from central to peripheral countries (Figure 2e). All in all, contagion episodes more than triple immunisation ones and register a significant increase coinciding with the recent crisis in sovereign debt markets from 2009 onwards, providing evidence of a reinforcement of the interconnection between debt markets. It is also notable that whilst contagion episodes are more frequent when the triggering countries in the causal relationships are peripheral (57% of the total, see Figures 2b and 2c), immunisation episodes are more usual when central countries are the triggers (65% of the total, see Figures 2d and 2e).

[Insert Figures 2 here]

4. Determinants of episodes of Granger-causality intensification/reduction

4.1. Econometric methodology

Once the episodes of intensification/reduction have been detected, we use ordered logit models to analyse their determinants. We define a new dependent variable (*y*) that takes the value 1 if we have detected an episode of Granger-causality reduction, 2 if there is no evidence of reduction or intensification (i. e., a "normal" relationship), and 3 if we have found a episode of intensification.

The ordered logit model is based on a continuous latent variable specified as:

$$y_{it}^{*} = x'_{it}\,\beta + u_{it} \qquad (5)$$

where y_{it}^{*} measures the degree of interconnection between EMU yield spreads, x_{it} is a vector of explanatory variables[20], β is an unknown parameter vector and u_{it} is the error term, which is assumed to follow a standard logistic distribution. In (5) the index i (i=1, ..., N) denotes the country pair and the index t (t=1, ..., T) indicates the period[21]. Unfortunately, y_{it}^{*} is an unobserved variable. Let us assume that y_{it} is the observed discrete variable that reflects the different degrees of interrelationship for EMU country

[19] Using the framework for grading the strength of the Granger-causality relationship proposed by Atukeren (2005) we obtain the same classification of episodes of intensification and reduction. Atukeren (2005)'s framework uses Postkitt and Tremayne (1987)'s posterior odds ratio test and Jeffreys (1961)'s Bayesian concept of grades of evidence.

[20] The regressors are listed in Appendix A. No intercept is included.

[21] As we will see in Section 4.2, in our case N=90 (the number of pair-wise relationships between sovereign bond yield spreads) and T=168 (monthly observations for 14 years).

pair *i* at time *t*. The relationship between the latent variable and the observed discrete one will be obtained from the model according to

$y_{it} = 1$ if $-\infty < y^*_{it} \leq \mu_1$, i=1, ..., N

$y_{it} = 2$ if $\mu_1 < y^*_{it} \leq \mu_2$, i=1, ..., N

$y_{it} = 3$ if $\mu_2 \leq y^*_{it} < +\infty$, i=1, ..., N

where μ_1 and μ_2 denote the threshold points that must satisfy that $\mu_1 < \mu_2$. Then

$$\Pr(y_{it} = 1) = \frac{1}{1+\exp(\mu_1 - x'_{it}\beta)}$$

$$\Pr(y_{it} = 2) = \frac{1}{1+\exp(\mu_2 - x'_{it}\beta)} - \frac{1}{1+\exp(\mu_1 - x'_{it}\beta)}$$

$$\Pr(y_{it} = 3) = 1 - \frac{1}{1+\exp(\mu_2 - x'_{it}\beta)}$$

4.2. Empirical evidence

Given that the instruments used as independent variables have been constructed with a monthly frequency, we also need to compute the dependent variable in the ordered logit models on a monthly basis. We calculate the monthly data by assigning a value of 1 if at least for half of the month there is evidence of reduction in the interconnection between yield spreads, a value of 3 if at least for half of the month there is evidence of Granger-causality intensification, and a value of 2 if at least for half of the month there is no evidence of either intensification or reduction.

We follow the general-to-specific approach (Hendry, 1995): our empirical analysis starts with a general unrestricted statistical model including all explanatory variables to capture the essential characteristics of the underlying dataset, testing it down by eliminating statistically insignificant variables, and checking the validity of the reductions at each stage to ensure congruence of the finally selected model[22]. We have also considered the possibility of both individual-specific effects (in each pair-wise relationship) and time-specific effects, by incorporating dummy variables, testing the joint significance of these dummies separately and once they are taken together. In Table 1 we report the final results of the ordered logit models estimated by maximum likelihood for five groups of countries: the first correspond to intensification/reduction causal relationship episodes within pairs of all EMU countries, the second within

[22] Note that this commonly used approach is a process driven by the data. We have also explored the possibility of adopting an alternative theory-driven approach using a specific-to-general modeling process by estimating equation (5) with each potential category of determinants having only one representative variable, leading to a multiplicity of models by the successive incorporation of additional variables. Interestingly, this alternative approach that explicitly acknowledges that there may be several models that are generated by the same data set (Hendry, 1995, 501) renders final specifications that are very close to the one obtained from the general-to-specific approach, giving further support to our results.

pairs of peripheral countries, the third from peripheral to central countries, the fourth within central countries, and lastly, the fifth from central to peripheral countries[23]. The z-statistics in that table are based on robust standard errors computed using the Huber-White quasi-maximum likelihood method. As can be seen, all the estimated coefficients are significant at the 1% level, and the individual and time dummies are jointly significant for the relationships between yield spreads in central countries, in peripheral countries and in those from peripheral to central countries, while for the relationships within all country pairs and those from central to peripheral countries we only find that the individual dummies are statistically significant.

The sign of the regression parameters can be immediately interpreted as determining whether the latent variable increases with the regressor. As can be seen, most of the estimated coefficients are positive, suggesting that an increase in the variable necessarily decreases the probability of being in the lowest category ($y_{it}=1$, i. e., immunisation) and increases the probability of being in the highest category ($y_{it}=3$, i. e., contagion). The converse is true for the negative sign coefficients associated with the consumer confidence indicator, the net position towards the rest of the world, and the market liquidity[24].

The empirical evidence presented in Table 1 does not support the occurrence of either "fundamentals-based" or "pure" contagion in euro area countries, but it suggests that a mixture of the two might have taken place. Specifically, when examining all pair-wise relationships, we find that not only some of the variables which capture both local and regional market sentiment are statistically significant, but that some local macroeconomic variables together with the instrument which gauges financial linkages are also relevant.

These findings are in line with the literature that states that the two types of contagion are not necessary mutually exclusive (see Dungey and Gajurel, 2013), and also with the results of Caporin *et al.* (2013), who, using a Bayesian quantile regression approach to measure contagion, obtain that there is no change in the intensity of the transmission of shocks between European countries during the onset of the sovereign debt crisis. Accordingly, the common shift observed in spreads might be the outcome of the "interdependence" (or "fundamentals-based" contagion) that has always been present in the markets. Indeed, recent European events have encouraged a new discussion of contagion. Unlike previous crises, in which the country responsible for spreading the shock was relatively clear, in the euro area sovereign debt

[23] All estimated threshold parameters differ significantly from each other, justifying our use of the ordered logit model since it indicates that the three categories should not be collapsed into two categories.

[24] Recall that an increase in consumer confidence may lead to a rise in investor confidence, so it seems reasonable to expect a negative relationship between it and the probability of occurrence of a contagion episode. Regarding the current-account-balance-to-GDP ratio, which is the instrument used as a proxy of the net position of the country towards the rest of the world, since this variable is defined as the difference between exports and imports an increase would have a negative effect on the probability of contagion. Finally, given that our measure of market liquidity is the overall amount of outstanding debt and that liquidity premium decreases with market size, one would expect a negative impact between this variable and contagion.

crisis several peripheral countries entered a fiscal crisis at roughly the same time. Indeed, when a group of countries share an exchange rate agreement (a common currency in the case of the euro area countries), crises tend to be clustered. It seems reasonable that, since the economic fundamentals of EMU countries are interconnected by their cross-border flows of goods, services, and capital, other variables beyond herding behaviour or sudden shifts in market confidence might also be at the origin of crisis propagation.

Nevertheless, we observe some disparities when analysing crisis transmission from the different groups of countries, peripheral or central. In the first case, the empirical evidence shows that, with the sole exception of Klose and Weigert (2012)'s index of euro instability, the variables that are significant are idiosyncratic (either shifts in market sentiment or in macrofundamentals). However in the second, regional market sentiment variables are much more relevant. These results suggest that, even though fundamental reasons are still present, transmission of the crisis when peripheral countries are the triggers is closer to the definition of "pure contagion" than when central countries are the triggers. An abnormal increase in the intensity of causal relationships from peripheral to other EMU countries (both peripheral and central) is mainly explained by idiosyncratic variables, although spillover effects cannot be attributed to herding behaviour alone. Conversely, transmission of the crisis from central countries is not only affected by local variables (market sentiment or fundamentals), but also by shifts in common regional variables. So, in the latter case, the abnormal increase in the intensity of causal relationships can clearly be identified as "fundamentals-based" contagion.

Looking across the columns[25], we see that, with regard to the variables measuring local market sentiment, we find a positive and significant effect for the stock-market volatility, the index of the fiscal stance and the credit rating (as expected, the consumer confidence indicator presents a negative sign). As for the local macrofundamentals, our results suggest a negative impact on contagion for both the net position towards the rest of the world and the market liquidity variable, and a positive effect for the country growth potential (proxied by the unemployment rate), the competitiveness (captured by the inflation rate) and the fiscal position (measured by the debt/GDP or the deficit/GDP ratios). In relation to indicators of regional market sentiment, we detect that the credit spread in European corporate bond market plays a decisive role in contagion episodes triggered by central countries, while the European 5-year CDS index in the financial and non-financial sectors ($ITRAXX_{FIN}$ and $ITRAXX_{NF}$) are relevant when examining all the pair relations and those from central countries. The variable euro instability which reflects the market expectation of the probability that at least one euro area country would have left the currency union at the end of 2013 is found to be positive and statistically significant in all cases, except for pairs relating central to peripheral countries. As regards the potential role of financial linkages in the contagion/immunisation

[25] We summarise the results by pointing out the main regularities. The reader is asked to browse through Table 1 to find evidence for particular group of countries of her/his special interest.

episodes, we find a significant effect for the variable measuring cross-border banking linkages when analysing the whole sample, supporting the close interconnection between the banking and the sovereign sectors.

Interestingly, none of variables measuring global market sentiment or regional macroeconomic variables was found to be statistically significant. With respect to the latter result, the fact that the dependent variable used in the analysis is the yield spread over the German bund might have cancelled out all common regional macroeconomic effects that might have adversely affected the economic fundamentals of several economies simultaneously, since they may have been captured by the evolution of the German yield. As for the global market sentiment, the result suggests that shifts in local or regional rather than global market sentiment are behind euro area debt crisis transmission. These results are in line with Gómez-Puig and Sosvilla-Rivero (2013b) who explore the breakpoints in EMU yield evolution and find that not only are half of the breakpoints directly connected to the euro sovereign debt crisis, but that 63% of them occur after November 2009 (once Papandreou's government announced the Greece's distressed debt position). Additionally, the absence of global market sentiment in the final regressions could also suggest that EMU has effectively acted as a true system, in which common conditions have had priority over global ones, and where only real differences (at least as perceived by market participants) could have explained the dissimilar evolution in sovereign yield spreads.

Finally, in Table 1 we also report the McFadden pseudo-R^2 statistic as a measure of goodness of the fit. As can be seen, it ranges from 0.3012 to 0.4123, suggesting the relative success of the estimated ordered logit regression models in predicting the values of the dependent variable within the sample when set against previous work with these models. Note that χ^2 and log likelihood diagnostic statistics are also satisfactory. As a further test to evaluate how well our estimated models account for the observations, in Table 1 we also present the proportion of outcomes correctly predicted by the estimated models, denoted as Count R^2. As can be seen, it ranges from 0.6015 to 0.7005, which can be considered a fairly good result.

5. Concluding remarks

In this paper, we have empirically investigated whether the transmission of the recent crisis in euro area sovereign debt markets was due to fundamentals-based or pure contagion. To this end, we have examined the behaviour of EMU sovereign bond yield spreads with respect to the German bund for a sample of both central (Austria, Belgium, Finland, France and the Netherlands) and peripheral countries (Greece, Ireland, Italy, Portugal and Spain) from January 1999 to December 2012.

Using daily data, we first applied a dynamic approach to analyse the evolution of the degree of Granger-causality within the 90 pairs of sovereign bond yield spreads in our sample. We aimed to detect episodes of significantly increased causality between them (which we associate with contagion) as well as episodes of significantly reduced interconnection (which we associate with immunisation).

We then used an ordered logit model with monthly data to assess whether a set of variables proposed in the theoretical and empirical literature measuring market sentiment (either global, regional and local), as well as macrofundamentals (both regional and local) and financial linkages have a significant influence in the occurrence of the detected episodes. The findings underline the importance of both variables proxying market sentiment and macrofundamentals in determining contagion and immunisation outcomes. Therefore, sovereign risk premium increase in the euro area during the European sovereign crisis was not due only to deteriorated debt sustainability in member countries; nor can it be explained only by herding behaviour or sudden shifts in market confidence and expectations. Nevertheless, our analysis highlights the relative importance of market participants' perceptions in episodes triggered by peripheral countries, while macroeconomic fundamentals seemed to play a major role in episodes where central countries are the triggers.

Our results may have some practical implications for investors and policymakers, and may provide theoretical insights for academic scholars interested in the behaviour of sovereign debt markets. Our methodology can be used as a tool to provide information regarding the factors underlying crisis transmission and related risks.

Appendix A: Definition of the explanatory variables in the ordered logistic regressions and data sources

A.1. Variables that measure local market sentiment.

Variable	Description	Source
Stock Returns	Differences of logged stock indices prices of the last and the first day of the month for each country.	Datastream
Stock Volatility	Monthly standard deviation of the daily returns of each country's stock market general index	Datastream
Index of Economic Policy Uncertainty (Germany, France, Italy, and Spain)	This index draws on the frequency of newspaper references to policy uncertainty and was created by Baker *et al.*, 2013.	www.policyuncertainty.com
Index of the Fiscal stance	This indicator compares a target level of the debt-GDP ratio at a given point in the future with a forecast based on the government budget constraint. It was created by Polito and Wickens (2011, 2012). Monthly data were linearly interpolated from yearly observations for the available data: 1999-2011	Provided by the authors.
Consumer Confidence Indicator	This index is built up by the European Commission which conducts regular harmonised surveys to consumers in each country.	European Commission (DG ECFIN)
Rating	Credit rating scale built up from Fitch, Moody's, S&P ratings for each country.	Bloomberg

A.2. Variables that measure regional market sentiment.

Variable	Description	Source
Stock Returns	Differences of logged stock indices (Eurostoxx-50) prices of the last and the first day of the month for each country.	Yahoo-finance
Stock Volatility (VSTOXX)	Eurostoxx-50 implied stock market volatility index. Monthly average of daily data.	www.stoxx.com
Index of Economic Policy Uncertainty (Europe)	Baker *et al.*, 2013.	www.policyuncertainty.com
Index of the Fiscal stance (Europe)	Polito and Wickens (2011, 2012). Monthly data were linearly interpolated from yearly observations for the available data: 1999-2011.	Provided by the authors.
Consumer Confidence Indicator (Eurozone)	European Commission	European Commission (DG ECFIN)
Credit Spread	Difference between the yields of the iBoxx indices containing BBB-rated European corporate bonds against the yields of the respective iBoxx index of AAA-rated European corporate bonds. Monthly average of daily data.	Datastream
$ITRAXX_{FIN}$ $ITRAXX_{NF}$	European 5-year CDS index in the financial and non-financial sectors: 2010:9-2012:12. Monthly average of daily data.	Bloomberg
EIRVIX-1Y EIRVIX-10Y	1-year and 10-year interest rate volatility index for the Eurozone based on the implied volatility quotes of caps (floors). This index was created by López and Navarro (2013) for the period 2004:1-2012:4.	Provided by the authors.
Euro Instability	Market expectation of the probability that at least one Euro area country will have left the currency union at the end of 2013, built up by Klose and Weigert (2012) for the period 2010:8-2012:8. Monthly average of daily data.	Provided by the authors.
Euro area default risk	Probability of two or more credit events, calculated by Lucas *et. al.* (2013): 2008:1-2012:12	Provided by the authors.

A.3. Variables that measure global market sentiment.

Variable	Description	Source
Stock Returns	Differences of logged stock indices (S&P 500) prices of the last and the first day of the month.	Datastream
Stock Volatility (VIX)	Chicago Board Options Exchange Market Volatility Index. (Implied volatility of S&P 500 index options), Monthly average of daily data.	Yahoo-Finance
Index of Economic Policy Uncertainty (United States)	Baker *et al.*, 2013.	www.policyuncertainty.com
Index of the Fiscal stance (United States)	Polito and Wickens (2011, 2012). Monthly data were linearly interpolated from yearly observations for the available data: 1999-2011	Provided by the authors.
Global Risk Aversion	The spread between 10-year fixed interest rates on US swaps and the yield on 10-year Moody's Seasoned AAA US corporate bonds. Monthly average of daily data.	Datastream
Kansas City Financial Stress Index	This measure is based on 11 financial market variables, each of which captures one or more key features of financial stress. It was created by Hakkio and Keeton (2009)	http://www.kansascityfed.org

A.4. Variables that measure local macrofundamentals.

Variable	Description	Source
Net position vis-à-vis the rest of the world	Current-account-balance-to-GDP Monthly data are linearly interpolated from quarterly observations.	OECD
Growth potential	Unemployment rate	Eurostat
Competitiveness	Inflation rate. HICP monthly interannual rate of growth	Eurostat
Fiscal Position	Government deficit-to-GDP and Government debt-to-GDP. Monthly data are linearly interpolated from quarterly observations.	Eurostat
Market liquidity	Domestic Debt Securities. Public Sector Amounts Outstanding (billions of US dollars) Monthly data are linearly interpolated from quarterly observations.	BIS Debt securities statistics. Table 18
Bank's debt	Banks' debt-to-GDP. Monthly data are linearly interpolated from quarterly observations for the GDP.	ECB's Monetary Financial Institutions balance sheets and own estimates. GDP has been obtained from Eurostat
Non-financial corporation's debt	Non-financial corporations' debt-to-GDP. Monthly data are linearly interpolated from quarterly observations for the GDP.	ECB's Monetary Financial Institutions balance sheets and own estimates. GDP has been obtained from Eurostat
Household's debt	Households' debt-to-GDP of country. Monthly data are linearly interpolated from quarterly observations for the GDP.	ECB's Monetary Financial Institutions balance sheets and own estimates. GDP has been obtained from Eurostat

A.5. Variables that measure regional macrofundamentals.

Variable	Description	Source
Net position vis-à-vis the rest of the world.	Current-account-balance-to-GDP Monthly data are linearly interpolated from quarterly observations.	OECD
Growth potential	Unemployment rate	Eurostat
Competitiveness	Inflation rate. HICP monthly interannual rate of growth	Eurostat
Fiscal Position	Government deficit-to-GDP and Government debt-to-GDP. Monthly data are linearly interpolated from quarterly observations.	Eurostat
Market liquidity	Domestic Debt Securities. Public Sector Amounts Outstanding (billions of US dollars) Monthly data are linearly interpolated from quarterly observations.	BIS Debt securities statistics. Table 18

A.6. Variables that measure financial linkages.

Variable	Description	Source
Foreign claims on bank debt	Foreign bank claims on banks debt-to-GDP. Monthly data are linearly interpolated from quarterly observations.	BIS Consolidated banking statistics. Table 9C. GDP has been obtained from the OECD.
Foreign claims on public debt	Foreign bank claims on government debt-to-GDP. Monthly data are linearly interpolated from quarterly observations.	BIS Consolidated banking statistics. Table 9C. GDP has been obtained from the OECD
Foreign claims on non-financial private debt.	Foreign bank claims on non-financial private debt-to-GDP. Monthly data are linearly interpolated from quarterly observations.	BIS Consolidated banking statistics. Table 9C. GDP has been obtained from the OECD.
Cross-border banking linkages	Percentage of the total foreign claims on country XX held by country YY's banks	BIS Consolidated banking statistics. Table 9D and own estimates.

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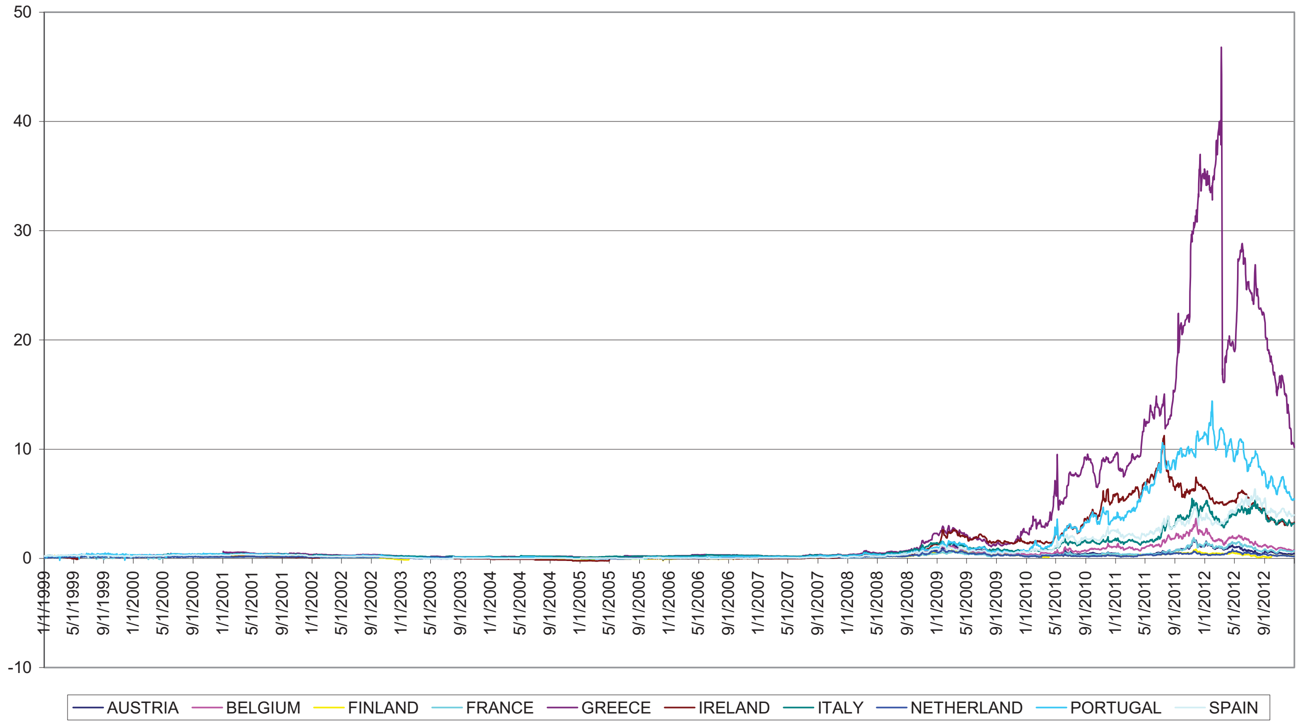
Figure 1. Daily 10-year sovereign yield spreads over Germany: 1999-2012



Figures 2: Contagion and immunisation episodes

Figure 2a: Within all EMU countries

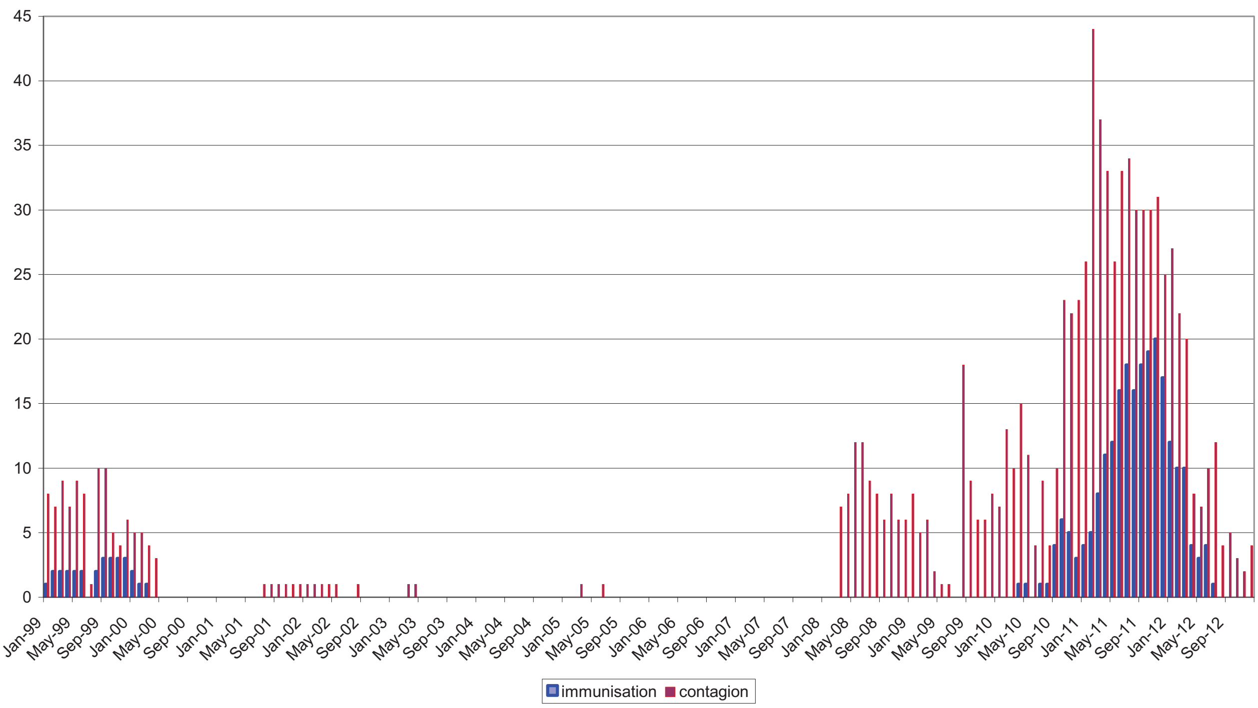


Figure 2b: Within peripheral countries

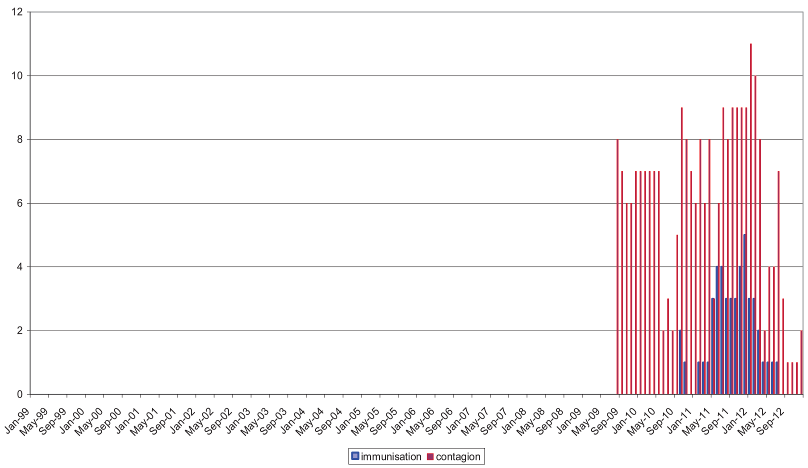


Figure 2c: From peripheral to central countries

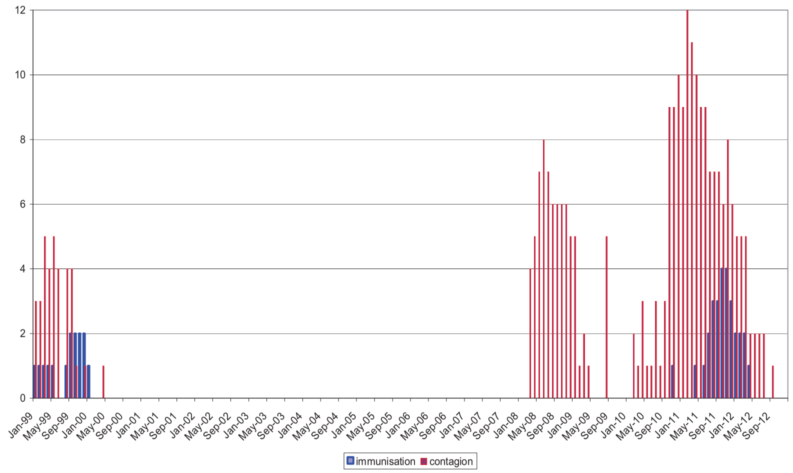


Figure 2d: Within central countries

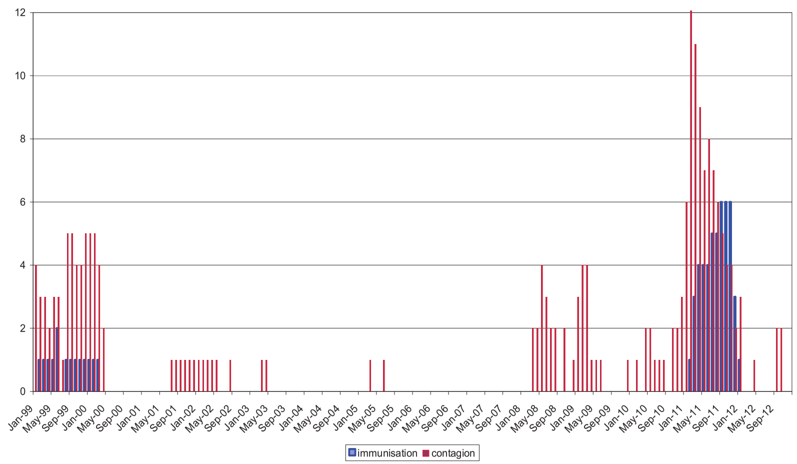


Figure 2e: From central to peripheral countries

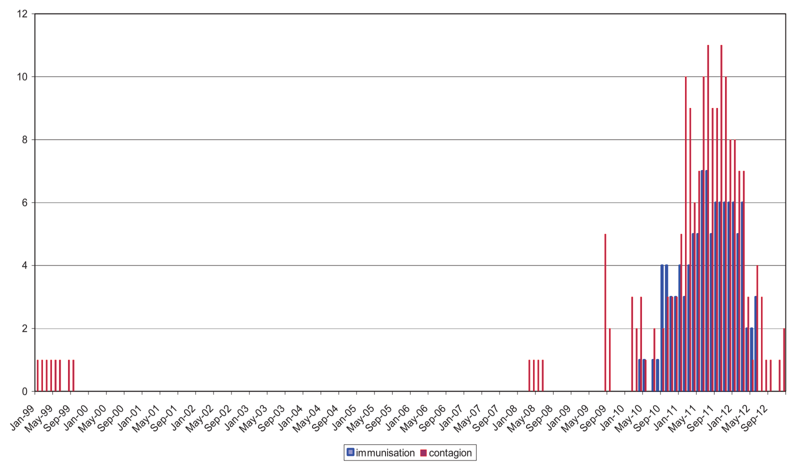


Table 1

	Variables		All Countries	Peripheral countries	Peripheral-Central Countries	Central Countries	Central-Peripheral countries
Local market sentiment	Stock Volatility	XXStockVol	40.0591* (2.2770)	-	-	232.4702* (2.2603)	129.9954* (2.3215)
		YYStockVol	110.6452* (4.6831)	-	-	-	112.6743* (2.6441)
	Index of the Fiscal stance	XXIFS	-	-	0.3692* (3.2514)	-	7.2646* (4.0722)
		YYIFS	5.2485* (3.5523)	1.6541* (4.8106)	-	-	9.2914* (3.4619)
	Consumer Confidence Indicator	XXCCI	-	-0.0071* (-3.8117)	-	-0.0636* (-2.5813)	-0 .2616* (-4.9239)
		YYCCI	-	-	-	0.0857* (2.5512)	-
	Rating	XXRating	0.0848* (3.1810)	0.1693* (2.7731)		1.0637* (6.1112)	1.5381* (3.9901)
		YYRating	0.0936* (3.1421)	0.1135* (2.3218)	-		0.1050* (2.2348)
Local macro fundamentals	Net position towards the rest of the world	XXCA	-	-	-	-0 .4219* (-2.9531)	-0.4478* (-2.8938)
	Growth potential	XXU	0.0872* (2.7941)	-	-	0 5567* (4.2046)	1.0412* (2.3647)
		YYU	0.0755* (2.0913)	0.1316* (2.1608)	-	0.6882* (2.9593)	0.0079* (2.4184)
	Competitiveness	XXINF	-	-	-	1.5741* (4.2012)	1.1760* (2.3647)
		YYINF	-	0.6720* (6.6105)	0 .1228* (2.6581)	-	-
	Fiscal Position	XXDEBT	0.0198* (2.7706)	-	13.8750* (2.8711)	0.2144* (2.7204)	0. 3124* (2.8453)
		YYDEBT	0.0151* (3.6103)	0.0574* (4.3457)	-	-	0.0152* (2.7915)
		XXDEF	0.0307* (2.9341)	-	-	-	0.1309* (2.4351)
	Market liquidity	XXLIQ	-	-0.0007* (-2.3510)	-	-0 .0122* (-2.6392)	-0.0082* (-2.4261)
		YYLIQ	-0.0005* (-2.8042)	-	-	-0 .0113* (-3.0032)	-
Regional market sentiment	Credit Spread	EURCreditSpread	-	-	-	0.5759* (2.9323)	0.7639* (2.8115)
	ITRAXX$_{FIN}$	EURITRAXX$_{FIN}$	0.0116* (2.1513)	-	-	0 .0706* (2.4239)	0.0169* (2.7514)
	ITRAXX$_{NF}$	EURITRAXX$_{NF}$	0.0407* (3.9031)	-	-	-	0.1448* (2.8941)
	Euro Instability	EURInstability	4.8159* (3.0452)	5.9879* (2.8215)	13.8750* (3.1422)	21.5812* (2.8635)	-
Financial Linkages	Cross-border banking linkages	XXYYBAN	0.0341* (3.0541)	-	-	-	-
Individual dummies			YES	YES	YES	YES	YES
Time dummies			NO	YES	YES	YES	NO
Pseudo R^2			0.3993	0.3535	0.3012	0.3733	0.4123
Count R^2			0.6015	0.6554	0.6490	0.7065	0.6552
Log likelihood			-992.8748	-579.6895	-540.0211	-259.3379	-226.4079
χ^2			601.76*	639.22*	298.30*	176.34*	200.01*
Prob individual dummies = 0			0.0000*	0.0000*	0.0000*	0.0000*	0.0000*
Prob time dummies = 0			0.8721	0.0000*	0.0000*	0.0458**	0.1558
Prob individual dummies and time dummies = 0			-	0.0000*	0.0000*	0.0000*	-
Observations			1408	864	1200	560	368
Countries			90	20	25	20	25

Notes: In the brackets below the parameter estimates are the corresponding z-statistics.
* and ** denote significance at the 1% and 5% level, respectively
Count R^2 is the proportion of outcomes correctly predicted by the model
XX denotes trigger country and YY receiver country in the pair-wise causal relationship

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